Copy No. 17

PRODUCTION ENGINEERING MEASURES

HIGH FREQUENCY TRANSISTOR

QUARTERLY PROGRESS REPORT NO. 6

FOR THE PERIOD

DECEMBER 20, 1962 TO MARCH 20, 1963

OBJECT:

ESTABLISH CAPABILITY TO MANUFACTURE THE GF-40036 GERMANIUM TRANSISTOR, 1000 MC., ON A PILOT LINE BASIS: PRODUCE ENGINEERING TEST SAMPLES AND A PILOT RUN

CONTRACT NO. DA-36-039-SC-85969
ORDER NO. 6024-PP-61-81-81

Prepared by: T. G. STOUDT

Approved by: T. W. MENDEL

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

ABSTRACT

The work accomplished on the GF-40036 Germanium Transistor during the sixth quarter since the date of award of the contract is herein reported.

Two additional lots of engineering test samples were shipped according to a mutual agreement between U. S. Army Electronics Materiel Agency and Western Electric Company.

Engineering effort was devoted to the following areas:

1. Developing improvements in epitaxial substrate material.
2. Developing improvements in diffusion of epitaxial material.
3. Continued evaluation of practical techniques and tooling for evaporation and wire bonding processes.
4. Continued discussions on a proposed Test Specification with representatives of U. S. Army Electronics Research & Development Laboratory, U. S. Army Electronics Materiel Support Agency, and U. S. Army Electronics Materiel Agency.

SECTION II

PURPOSE

The purpose of the work provided in the contract is:

1. To provide engineering necessary to establish production design of a 1000 Mc. Germanium Transistor.
2. To manufacture engineering test samples of the above device.
3. To develop and provide limited production equipment for the processes established for a pilot line.
4. To produce pilot run samples on machinery of point 3 above.
5. To provide quarterly, final engineering, Bill of Materials, and general (for Step II) reports as per time schedule in contract.

SECTION III

NARRATIVE AND DATA

This section reports the progress made during the sixth quarter after the effective date of contract.

1.0 MATERIAL PREPARATION

1.1 Substrates - T. G. Mills

Of the Cleaning Techniques investigated, two methods seem feasible. These are Mechanical Polishing and Etching or Electro-mechanical Polishing. As reported in Progress Report No. 5, mechanical polished slices when given a slight clean-up etch reveal many scratches. However, when etched to remove approximately 1.5 mils, a mechanically polished slice is usually free of visible scratches. The electro-mechanical polishing process generally produces a slice free of scratches. Further investigations were made in relating pits in substrates to these found in the layer. There is a positive correlation between the number of pits on the substrate and on the epi-layer. More investigations are required in detecting and monitoring substrate material defects.

1.2 Epitaxial Layer:

Evaluation of epitaxial layers grown on a vertical epi-machine revealed that 70% of slices had layers with a thickness variation $\pm$ 3.2% over the entire slice. Additional studies were made in a resistivity measuring technique to determine resistivity at a given depth from the diffused junction.

The uniformity of resistivity within a slice may be seen from Figure No. 1 where the resistivity = 2.4 ± 0.4 ohm-cm. (at 1 μ from the junction). Run-to-run reproducibility depends on the thickness and growth parameters. It was confirmed that there is a positive correlation of thickness vs. resistivity. This dependence of resistivity on layer thickness is expected because of out-diffusion of dopant from the substrate.

Additional sutdies are required in doping the epitaxial layer to given concentration.

1.3 <u>Diffusion</u> - W. H. Eckton, Jr.

The "closed box" diffusion furnace method was continued during this reporting period. The percentage variation was discussed in Quarterly Progress Report No. 4.

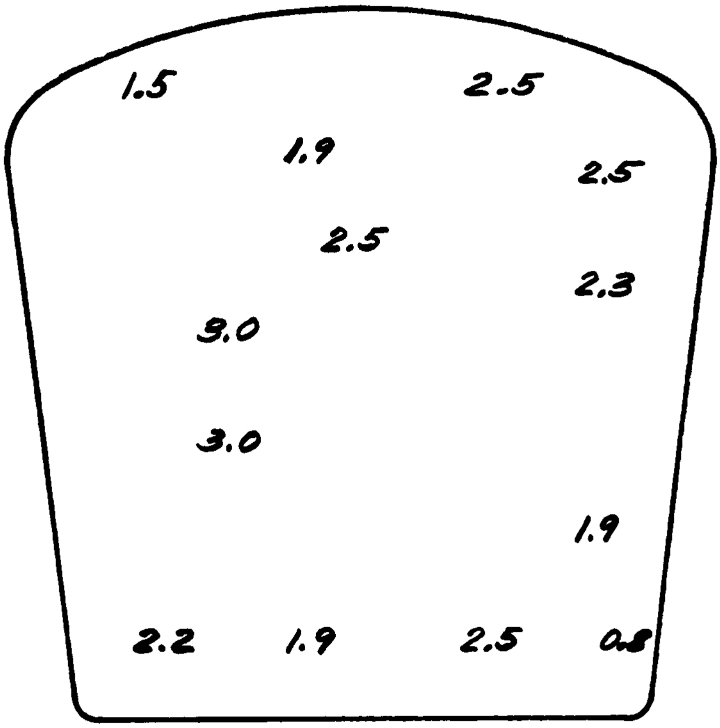
The use of an additional high surface concentration arsenic diffusion to reduce base resistance has resulted in extremely low emitter breakdowns for this device.

A heavier concentration antimony diffusion resulted in an improvement in device high frequency performance, however, D.C. and low frequency gain parameters were degraded.

1.4 <u>Evaporation</u> - W. A. Sponsler

Evaporation effort included utilization of higher vacuum and improved trapping techniques to minimize contamination from the pumping system. The results of varying the alloy penetration of the evaporated contacts was studied and it was confirmed that correction could be made for variations in diffused junction depth in order to maintain good high frequency performance.

Investigation was pursued into evaporant source holders and heaters, including such items as crucible design to provide smaller effective source area, crucible material, and source heating methods. An attempt is being made to heat the evaporant by induction methods. Initially the sealed R.F. feed-throughs mounted in the evaporator base plate were not adequate due to the high R.F. loss encountered. A new design of feed-through is being attempted at the present time.



RESISTIVITY PROFILE

FIGURE NO. 1

2.0 HEADER FABRICATION - A. K. Kreider

The glass clearform pellet mentioned in Quarterly Progress Report No. 1 has been replaced with glass tubing and cane. The large quantity of small bubbles present in the clearform pellet hampered visual examination of the glass-to-metal seal area. Subsequent chemical cleaning operations opened many of the bubbles resulting in small "traps".

The modified 0.0065" thick connector discussed in Quarterly Progress Report No. 5 proved satisfactory. The welding projection improved connector-platform weld strength and eliminated glass cracks in this area. A new welding electrode was designed to make each connector-post weld separately. The electrode improved the strength, position and reliability characteristics of these welds. See Figure No. 2 and Figure No. 3.

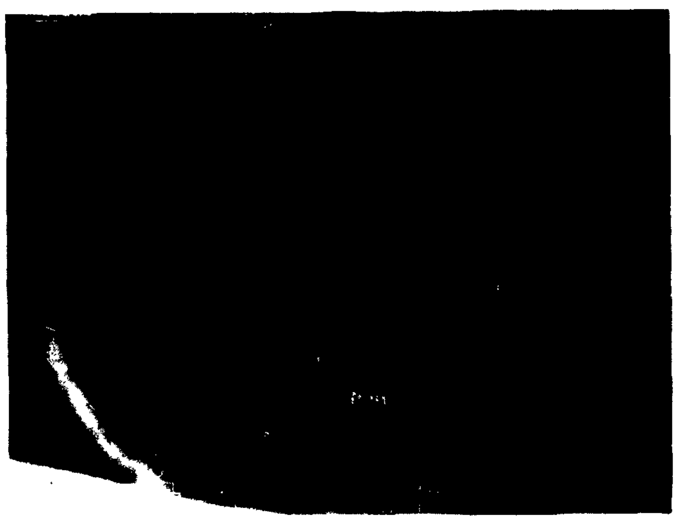
The connector cutting operation has been performed by an airbrasive tool utilizing the cutting effects of abrasive powder traveling at high speeds. Improved tooling has increased the quality of the connector and reduced the cost of this fabrication.

The development of a special plating barrel has improved plating yields and reduced costs of this operation.

Future effort will be directed at improving yields and dimensional qualities. A connector with "coined ribs" will be introduced to further strengthen the connector.

ONE PIECE CONNECTOR AFTER WELDING

FIGURE NO. 2



CONNECTOR AFTER CUTTING OPERATION

FIGURE NO. 3

3.0 MECHANICAL ASSEMBLY - T. G. Stoudt

3.1 Wire Bonding

The usual wire bonding process with manual bonders has continued. Several engineering evaluations were made with temporary setups of special microscopes obtained from commercial sources. It is desirable to obtain magnification at 200 power or greater to enlarge the view of the contact stripes. It is also desirable to have both bonding points, at the stripe and at the tab, in focus at the same setting because of the difficulty in handling the fragile gold wire. However, most of the microscopes evaluated lacked working spece for the bonding wedge or in depth perception. Effort will continue in this area to reduce the cost of wire bonding operation and losses from unsuitable bonds.

4.0 ELECTRICAL EVALUATION - M. M. Hower, W. H. Eckton, Jr.

Unilateral gain and Y - parameters, from which unilateral gain can be calculated, have been measured on a number of units and very good agreement has been obtained. Unilateral gain is calculated from Mason's General Unilaterialization Theorem (*) in which

$$U = \frac{\left| Y_{21} - Y_{12} \right|^2}{4 \left(G_{11} G_{22} - G_{12} G_{21} \right)}$$

* Reference: "Power Gain in Feedback Amplifier" by S. J. Mason, Page 23, Transactions IRE, PGCT, 1954.

Figure No. 4 shows the connections for measurement of unilateral gain.

The characterization of noise figure for 50 ohm source impedence has continued. In addition, attempts are being made to optimize noise performance and to determine the optimum source admittance for these devices. It is expected that this procedure will lead to improved device and amplifier design.

4.1 ENGINEERING TEST SAMPLES

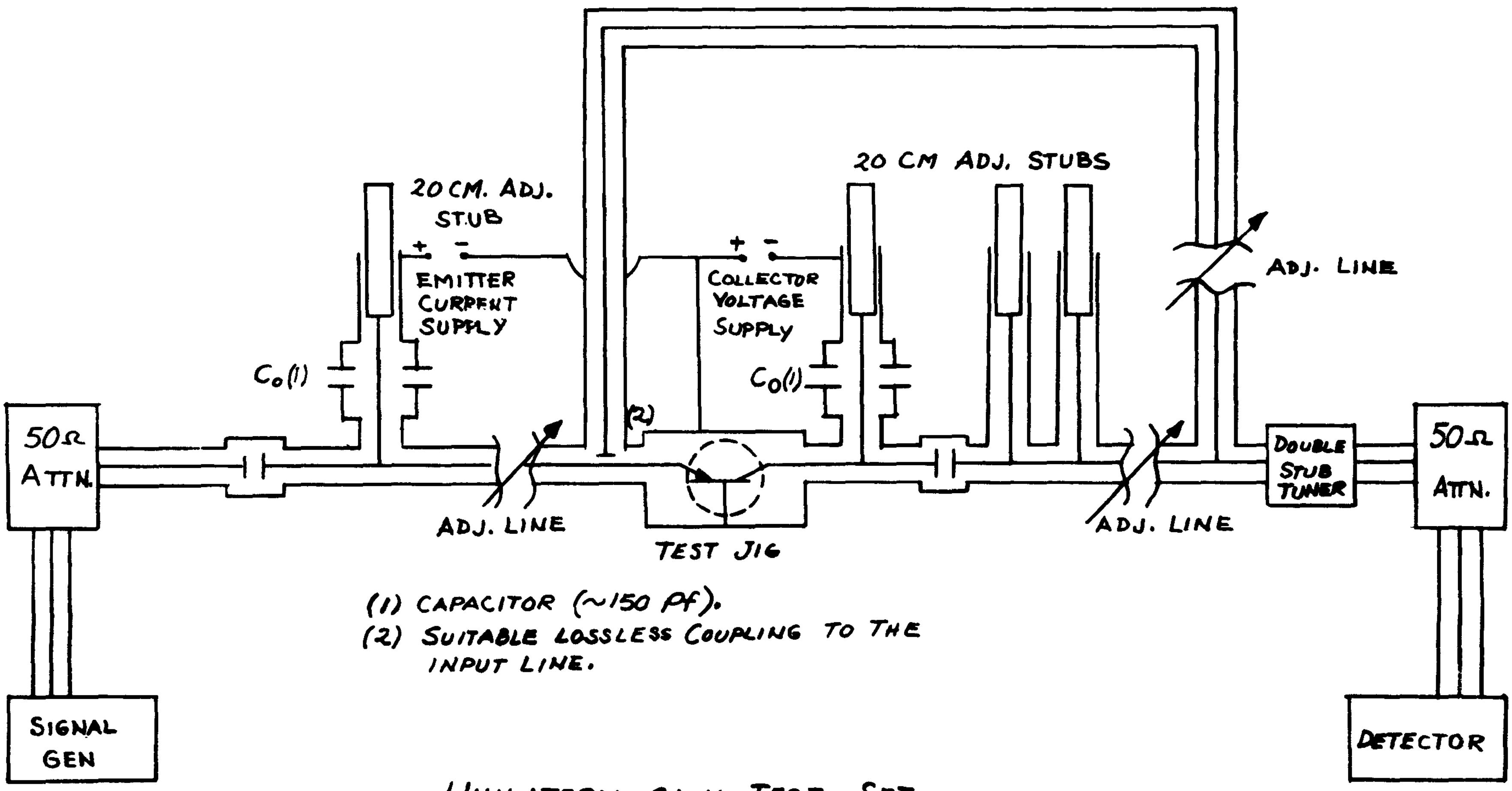
The sixth shipment of engineering test samples was made in January, 1963. Units were identified by numbers 201 to 225 inclusive. Test data for these units is listed on Figure No. 5.

The seventh shipment of engineering test samples was made in March, 1963. Units were identified by numbers 226 to 250 inclusive. Test data for these units is listed on Figure No. 6.

Power gain measurement was obtained with equipment assembled as per sketch MES-53053 shown on Page 13 of Quarterly Progress Report No. 3.

5.0 PROCESS CONTROL - R. L. Bryan

The process control procedures which were outlined in Quarterly Progress Report No. 4 are continuing. One quality control team meeting was held during this period for review of wire bonding process controls. Slight revisions were made in these controls as a result of quality control team agreement. Revisions of the remaining process control checks were considered unnecessary at this time by the members of the quality control team.



UNILATERAL GAIN TEST SET

FIGURE NO. 4

DA-36-039-SC-85969 Order No. 6024-PP-61-81-81 Engr. Test Samples GF-40036

									IE = 5mA VCB = -5V			
							1000~		1000 MC			
	IC=-100uA	IE=-100uA	IC=-1mA	VCB=-5V	IC=-5mA VCE=-5V	VCB=-5V	(1 + hfb)	hib				VCB=-5V IE=3mA
UNIT NO.	BVCBO	BVEBO	BVCEO	ICBO	hFE	Cdep	5 MA	5 MA	POWER GAIN *db	REV. GAIN db	GAIN FIG. db	NOISE FIG.
201	26	0.5	24	0.4	8.0	0.35	.066	8.9	11.5	-19.5	31.0	7.5
202	30	0.5	25	0.2	6.8	0.29	.100	10.0	15.6	-16.0	31.6	7.5
203	23	0.4	19	0.5	9.2	0.37	.070	14.0	14.2	-16.0	30.2	7.8
204	24	0.3	23	0.1	8.6	0.39	.061	9.0	16.6	-15.6	32.2	8.8
205	20	0.5	19	0.8	6.6	0.27	.100	10.0	14.0	-20.0	34.0	8.1
206	30	0.5	23	0.4	8.0	0.27	.068	7.0	15.4	-19.4	34.8	6.3
207	30	0.3	24	0.1	8.0	0.22	.088	15.0	11.5	-20.6	32.1	7.1
208	22	0.5	17	1.4	10.4	0.42	.066	9.1	17.4	-13.9	31.3	6.4
209	25	0.5	22	0.1	5.8	0.33	.080	7.8	14.6	-18.1	32.7	7.7
210	31	0.5	26	0.6	5.4	0.27	.094	11.0	14.0	-19.5	33.5	6.8
211	22	0.5	18	0.4	6.1	0.40	.091	11.0	14.6	-15.6	30.2	8.3
212	17	0.5	13	3.0	8.9	0.51	.045	6.6	15.6	-15.2	30.8	7.6
213	26	0.6	19	0.3	8.1	0.40	.078	7.8	16.2	-15.6	31.8	6.9
214	22	0.6	16	0.2	10.2	0.46	.060	7.8	16.3	-14.0	30.3	6.6
215	15	0.5	14	0.3	11.9	0.41	.050	10.0	14.6	-13.6	30.2	9.1
216	16	0.7	10	1.0	35.7	0.56	.015	14.0	15.6	-16.4	32.0	6.4
217	22	0.6	15	0.4	22.7	0.36	.029	7.9	13.9	-17.8	31.7	6.4
218	12	0.7	7	0.4	11.6	0.60	.022	4.0	14.4	-16.4	30.8	6.5
219	15	0.5	8	0.1	13.2	0.60	.034	6.6	18.0	-15.6	33.6	6.5
220	30	0.5	21	2.6	12.2	0.30	.041	6.6	15.0	-17.4	32.4	6.1
221	29	0.4	24	0.4	6.7	0.36	.068	8.8	14.2	-17.2	31.4	7.9
222	22	0.5	17	0.8	11.4	0.35	.061	11.0	13.5	-17.8	31.3	7.1
223	27	0.2	24	0.4	12.2	0.44	.032	6.6	16.0	-14.1	30.1	5.2
224	28	0.5	24	0.3	4.5	0.34	.130	11.0	15.8	-15.4	31.2	7.4
225	24	0.2	23	0.5	4.1	0.45	.074	8.0	15.2	-18.8	34.0	9.1

*Power Gain measurement of above units was recorded using the assembly of measurement components as shown on drawing MES-53053. Stable gain measurements are thereby obtainable because the input network tuning is eliminated.

FIGURE NO. 5

							I_E = 5mA, V_{CB} = -5V						
							1000 ~		1000 MC				
	I_C=-100uA	I_E=-100uA	I_C=-1mA	V_{CB}=-5V	I_C=-5mA V_{CB}=-5V	V_{CB}=-5V	(1 + hfb)	hib				V_{CB}=-5V I_E=5mA	V_{CB}=-5V I_E=5mA
UNIT NO.	BVCBO	BVEBO	BVCEO	ICBO	hFE	Cdep	5 MA	5 MA	POWER GAIN *db	REV. GAIN db	GAIN FIG. db	NOISE FIG.	U● db
226	29	0.5	22	0.8	7.5	0.36	.082	10.0	14.2	-16.4	30.6	7.90	10.3
227	17	0.6	14	0.8	12.8	0.41	.044	7.6	19.0	-13.6	32.6	7.68	14.7
228	20	0.6	12	1.2	17.8	0.41	.054	6.8	19.5	-13.2	32.7	8.01	14.8
229	28	0.4	20	0.4	11.1	0.29	.048	7.9	15.2	-17.0	32.2	7.76	11.7
230	28	0.4	24	0.1	5.0	0.36	.096	10.0	15.2	-16.8	32.0	8.72	12.7
231	30	0.3	27	0.1	7.8	0.35	.070	9.8	14.8	-17.2	33.0	7.95	13.5
232	33	0.6	25	0.1	6.7	0.32	.090	7.4	15.8	-20.8	36.6	7.54	13.4
233	26	0.4	21	0.1	10.4	0.35	.058	7.6	18.0	-15.7	33.7	7.58	14.5
234	23	0.6	15	0.1	27.8	0.45	.022	5.8	17.4	-13.5	30.9	6.86	14.0
235	24	0.6	20	0.2	12.8	0.40	.048	7.6	18.1	-13.1	31.2	7.27	14.5
236	23	0.6	18	0.1	16.7	0.42	.036	6.2	18.4	-11.8	30.2	7.81	14.6
237	24	0.6	17	0.2	14.7	0.46	.042	7.0	21.4	-10.1	31.5	6.60	14.8
238	28	0.6	19	0.6	17.2	0.42	.045	8.5	12.4	-18.5	30.9	6.68	14.0
239	28	0.4	23	1.0	7.3	0.37	.085	9.1	13.6	-17.4	31.0	7.35	13.4
240	28	0.5	25	0.3	6.5	0.35	.088	9.0	16.2	-15.8	32.0	7.72	12.9
241	30	0.5	21	0.2	14.3	0.32	.039	11.0	12.0	-19.6	31.6	8.20	11.1
242	17	0.6	16	0.1	6.9	0.38	.092	8.2	10.5	-22.0	32.5	8.02	13.4
243	17	0.6	10	0.2	33.3	0.57	.024	7.4	16.9	-17.2	34.1	7.26	13.4
244	17	0.6	12	0.1	16.7	0.45	.039	6.8	14.6	-16.8	31.4	7.35	15.6
245	12	0.5	14	0.2	18.5	0.36	.042	8.2	11.4	-21.0	32.4	9.04	14.5
246	23	0.6	18	0.1	5.6	0.39	.110	9.9	13.0	-20.2	33.0	8.87	14.2
247	24	0.5	20	0.1	5.4	0.29	.092	8.6	11.9	-20.4	32.3	8.74	14.0
248	23	0.5	16	0.3	16.7	0.39	.038	8.0	12.1	-18.4	30.5	8.04	13.1
249	13	0.6	14	0.4	13.2	0.36	.038	7.6	13.0	-18.8	31.8	8.04	11.5
250	35	0.7	21	0.1	19.2	0.26	.033	6.6	14.4	-19.5	33.9	6.60	12.2

*Power Gain measurement of above units was recorded using the assembly of measurement components as shown on drawing MES-53053. Stable gain measurements are thereby obtainable because the input network tuning is eliminated.

● Calculated Unilateral Gain: $U = \dfrac{\left| Y_{21} - Y_{12} \right|^2}{4\,(G_{11}G_{22} - G_{12}G_{21})}$

FIGURE NO. 6

SECTION IV

CONCLUSIONS

Engineering effort must continue in the various areas of material preparation for manufacturing a high frequency transistor. These areas include; cleaning substrate material, producing uniform epitaxial layers, doping, diffusion, and evaporation.

The mechanical processes are resolved excepting the problem of optics in wire bonding.

The revision to the connector tab on the modified header assembly has increased centrifuge capability and decreased loss of headers in inspection due to glass cracks.

Improvements in germanium epitaxial material have resulted in production of units with gain figures of 30 db and higher.

SECTION V

PROGRAM FOR NEXT INTERVAL

Effort will continue in the material preparation areas.

A feasibility study will be pursued to investigate whether fine gold wire can be manufactured on spools and whether the resultant wire can be readily "stitch bonded".

Further meetings will be arranged with government personnel relative to resolving the proposed device testing specifications.

Additional facilities will be added to the pilot line to provide for all operations necessary to manufacture this transistor.

SECTION VI

IDENTIFICATION OF PERSONNEL

The following professional personnel were active on the study throughout the reported period:

R. L. Bryan - WE - Planning Engineer

W. H. Eckton, Jr. - BTL - Member of Technical Staff

M. M. Hower - BTL - Member of Technical Staff

T. W. Mendel - WE - Department Chief

T. G. Mills - WE - Development Engineer

A. L. Nester - WE - Planning Engineer

W. A. Sponsler - WE - Development Engineer

T. G. Stoudt - WE - Senior Engineer

R. W. Westberg - BTL - Supervisor

The following professional person left the study during the reported period:

L. R. Sell - WE - Development Engineer

The following professional person was added to the study during the reported period:

A. K. Kreider - WE - Engineering Associate

A. K. Kreider graduated from Lebanon Senior High School in 1953. Attended Pennsylvania State College Center in York, Pennsylvania. Graduated in 1956 with Associate Degree in Electrical Engineering.

Joined Western Electric Company in 1956 as Engineering Associate in Semi-Conductor Sub-assembly Engineering Department. Was transferred to operating supervisor in piece parts manufacture from 1959 to 1961. Presently is an Engineering Associate in piece parts manufacture engineering.